Engineers Australia

Ridgeway Water Supply Scheme of Hobart

Engineering Heritage Report

Ridgeway Reservoir (Image Courtesy of TasWater)

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Contents

1. Introduction

The Ridgeway Water Supply Scheme was initially created to augment the supply of water to the citizens of Hobart and increase reliability of the supply to residents of the upper suburbs, who were having severe shortages during the dry periods (when the Upper & Lower Reservoirs were low); however, Ridgeway is now used mainly to supply residents in the Kingborough region.

The Scheme includes both the Ridgeway Reservoir and the pipeline from the North-West Bay River to the reservoir which were constructed between 1911 and 1918. This is only a snapshot of the life of the scheme as its inception was around 1905[1], with construction defects and age requiring repairs and improvements continuing up until the present day. The contract for the reservoir was awarded to Cornwell and Co.[2], whilst the pipeline was completed through individual contracts, the most significant of which was the contract for concrete piping with Hume Bros. Cement Iron Company Ltd (Hume)[3].

The scheme holds present significance as a part of Mt. Wellington's recreational tracks; although, various parts of the scheme, such as the Siphon and concrete pipeline, aren't clearly visible from the Pipeline Track, due to vegetation and distance to items (e.g. the Siphon drops around 100m into the Valley along the Plains Rivulet and can only be accessed by a steep track). The reservoir isn't part of the main track and doesn't have public access, but the scheme was of significance to Hobart residents in doubling their supply and enabling expansion and adequate supply to suburbs above the old reservoirs; the increased water pressure to upper suburbs allowed such a development. The scheme was also significant at the time in that its development meant the permanent divestment of the Longley residents' water rights through the Hobart Water Bill[4] in 1905, who provided an obstacle to the development of Hobart's water supply, but who are now the major recipients of the Ridgeway supply since the development of the Lake Fenton and West Derwent schemes.

The Ridgeway Scheme has not come under much attention in terms of Heritage, with focus being opted for the Waterworks (Upper and Lower Reservoir, and connected works). It has been included in Heritage discussions, including the '*Hobart Mountain Water Supply System Conservation Management Plan*' (1), however there are some historical inaccuracies present and the reservoir and associated sites were not investigated.

This report aims to provide an insight into the areas not generally covered in Heritage research, focusing more closely on the nature of engineering and the processes used by engineers in this period. Engineering heritage does not limit itself to just the historic and social value of an area, but also how it has helped shape our future and the lessons we can learn from the past.

[1]HOBART WATER SUPPLY, *The Mercury*, 11 August 1905, p.6.
[2]RIDGEWAY RESERVOIR, *The Mercury*, 7 February 1911, p.5.
[3]HOBART WATER SUPPLY, *The Mercury*, 13 April 1916, p.3.
[4]THE HOBART WATER BILL, *The Mercury*, 20 September 1905, p.4.

1.1. Acknowledgements

This report has primarily been prepared as part of an industrial experience project, expanding the understanding and awareness of young engineers seeking experience in industry, but could not have been completed without assistance. The author wishes to thank and acknowledge the contributions of:

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Engineering Heritage Tasmania (EHT)

The staff of the State Library of Tasmania & State Archives

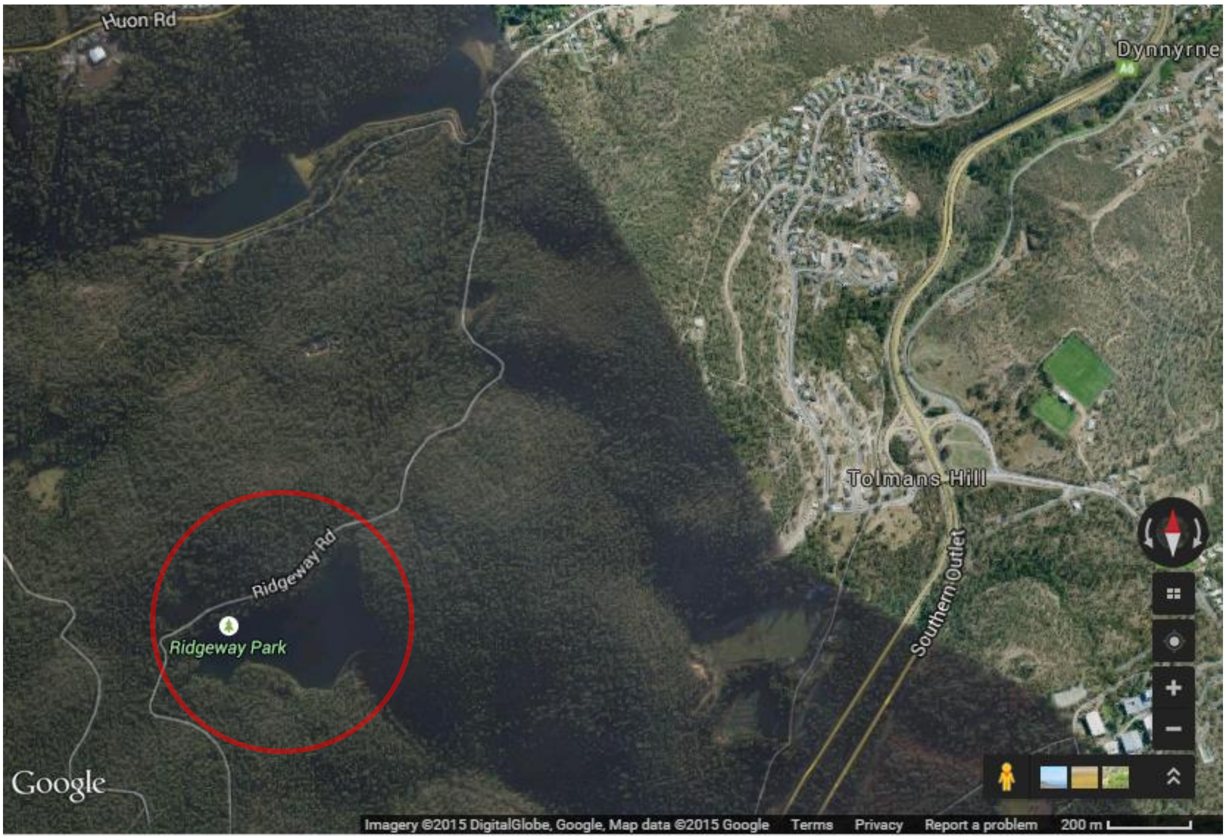
Thanks are particularly due to Peter Spratt and Ian Cooper, the EHT mentors who assisted with preparation and direction of this heritage project.

Thanks are also due to Fraser White, Project Engineer at TasWater, who assisted with accessing information about recent projects at Ridgeway and organised site visits for the Industrial Experience students.

1.2. Location

Coordinates: -42.917352, 147.291688

1.1. Ridgeway Reservoir Aerial View (Image Courtesy of Google)



2. History

2.1. Need for a new Supply

Debate over the expansion of Hobart's water supply increased in frequency in the early 1900s over concerns of shortages due to dry weather. In 1905, these concerns prompted the Hobart City Council (HCC) to begin assessments for potential sources of supply. The survey that prompted the Ridgeway Scheme occurred in early August of that year and the report, given by Dr J. C. Elkington, the Chief Health Officer, and E. A. Counsel, the Surveyor-General, recommended securing their rights to half the headwaters of the North-West Bay River supply in perpetuity, as the old agreement was soon to expire[5]. Their report also recommended the addition of an extra reservoir which was considered further and in 1906 two proposals were set before the HCC; that of a storage reservoir at Ridgeway, to store water from the North-West Bay River and tap into other sources along the southern slopes of the mountain, and the other proposal, to construct an impounding reservoir higher up the mountain[6].

2.2. Design

The first proposal was considered and further investigation and surveys of the Ridgeway site in 1907 and 1908 were completed. Surveys involved the digging of several trial holes. A significant fissure running at right angles to the proposed wall of the reservoir necessitated investigation to ensure a sound foundation; previous issues caused by superficial examinations of the geological features of reservoir sites[7] encouraged extra care to be taken with the construction of this dam. A trial shaft was initially sunk 47m below the valley floor with the fissure decreasing to 1.8m in width. The shaft finally reached 25.6m below the foundation or 86.9m below the top of Ridgeway's dam wall (See Figure 3.2.). R. S. Milles, the City Surveyor, expressed his confidence in making the fissure water-tight.

"*The pug seams against the walls were found to be tight and dry as soon as opened up, and the intervening concretionary mass being hard and fairly compact at the lower levels.*" (2)

In 1908 the HCC enlisted the aid of L. A. B. Wade, the Chief of Irrigation and Drainage of the NSW Government and experienced in dam design, to report on the proposed site for the reservoir. These reports led to a final recommendation by Wade in 1910[8] to construct a combination constant radius arch-gravity abutment dam for Ridgeway. Specifications and plans were completed[9] by Milles, who had moved to the position of Director of the Waterworks Committee. Rock-fill and Hydraulic-fill dam types had also been considered, but sufficient material of adequate quality could not be found locally.

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[5] HOBART WATER SUPPLY, 1905, loc.cit.
[6] THE HOBART WATER SUPPLY, *The Mercury*, 23 May 1906, p.4.
[7] The Upper and Lower Reservoirs of the Waterworks Reserve included geological oversights in the construction of their embankments which caused leakages and the failure of the Lower Reservoir, incurring significant costs to rectify.
[8] RIDGEWAY STORAGE RESERVOIR, *The Mercury*, 5 April 1910, p.2.
[9] RIDGEWAY RESERVOIR, *The Mercury*, 4 March 1911, p.5.

2.3. Construction

The contract for construction was awarded to Cornwell and Co. for £56,384 (3) and work began with the turning of the sod[10] on 21st March, 1911. The construction of Ridgeway Dam was plagued with problems, including various worker strikes based on wage changes and the supply of equipment[11, 12]. The Contractor had a strained relationship with the HCC and due to changes in specification[13, 14]and in lack of progress[15], their contract was frustrated and the HCC took over the work[16]. The Contractor, due to their insufficient capital and leadership, faced liquidation and the HCC sought reparations[17] in terms of equipment and plant used.

One of the changes in specification was in the choice of plum stone and concrete aggregate in the dam. The contract stated the use of bluestone (dolerite) for plum, yet the contractors stated that they were unable to find adequate supplies of the stone nearby and requested that freestone (sandstone) be used instead[18]. The amendment was approved; however the sourcing of freestone and the sand they took from the same quarry caused issues, to be resolved after its completion.

The other change was taken in order to ensure that the dam could be raised in the future. Several schemes were presented to the HCC; with Scheme 'I' was chosen. Under this scheme the dam was constructed 6.1m below the original design, with the thickness increased to allow the dam height to be later raised by 9.1m (3.05m above the original design). The capacity at the first stage (6.1m below design) was estimated to be 310.4 Ml, with capacity increased to 783.6Ml at full height[19]. This scheme also described the composition of the plum concrete used, with the "*arch portion above 85ft. level in solid concrete, arch below 85ft. level in bluestone plum concrete, wings in freestone plum concrete.*" (4) In comparing the reservoir to other works an Alderman of HCC thought they were getting the supply cheaply. He mentioned a reservoir being built in Sydney to hold 130 million gallons (492 Ml) was estimated to cost £4,000,000[20]. It appears that the scheme was adjusted to raise the dam to its full height (761Ml capacity) between the decision to go with scheme 'I' in 1913 and 1915 where works described progress: "*The arched portion of dam has been built to a height of 20ft above ground, or an extreme height of 183ft. from bottom of shaft in foundations. The arch has to be raised another 90ft.*"[21]

The ceremony for completion of the dam wall[22] was held in 1917, the year following the commencement of works for the associated Ridgeway pipeline, the North-West Bay Pipeline.

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10 HOBART WATER SCHEME, *The Mercury*, 22 March 1911, p.5.
11 RIDGEWAY RESERVOIR STRIKE, *The Mercury*, 19 April 1911, p.5.
12 RIDGEWAY RESERVOIR, *The Mercury*, 31 December 1912, p.5.
13 HOBART COUNCIL. THE RIDGEWAY RESERVOIR, *The Mercury*, 13 November 1912, p.3.
14 RIDGEWAY RESERVOIR, *The Mercury*, 7 March 1913, p.6.
15 RIDGEWAY RESERVOIR CONTRACT, *The Mercury*, 29 April 1913, p.4.
16 THE RIDGEWAY RESERVOIR, *The Mercury*, 10 June 1914, p.4.
17 NEWS OF THE DAY, *The Mercury*, 4 August 1914, p.4.
18 HOBART COUNCIL. THE RIDGEWAY RESERVOIR, 1912, loc.cit.
19 RIDGEWAY RESERVOIR. QUESTION OF INCREASED CAPACITY, *The Mercury*, 7 March 1913, p. 6.
20 Ibid.
21 WATER SUPPLY. RIDGEWAY RESERVOIR AND NORTH-WEST BAY UNDERTAKINGS, *The Mercury*, 7 December 1915, p. 7.
22 RIDGEWAY RESERVOIR, *The Mercury*, 7 June 1917, p.6.

2.4. North-West Bay Pipeline

The contract for the significant portion of the pipeline was awarded to Hume in 1916[23] after investigations by J. C. Ross, the City Engineer (5), found that their innovative reinforced concrete (humespun[24]) pipes would be suitable under the pressures involved. The opportunity for Hume was created by scarcity of usual pipe materials during WWI, namely iron. This shortage inflated the pricing of iron and steel pipes which meant that Ross was unable to secure pipes within his estimates for the pipeline; the lowest tender for the pipeline was £4,500 over Ross' estimate (6). This encouraged Ross to search further afield for pipes constructed of material other than iron, which led him to Hume and their humespun pipes.

The construction and testing[25] of this pipeline held widespread curiosity for the engineering community since it was the first significant use of concrete piping under hydraulic pressures. Upon completion, the pipeline was tested to 1MPa, 40% higher than the working pressure without any significant defects discovered; not only were these pipes significantly cheaper to source during WWI[26], they didn't suffer the longevity issues due to rusting that iron and steel did, and were lighter than steel which reduced cartage costs. The pipeline collected water from the southern catchments of the Mountain including from the North-West Bay River, Long Creek, Fork Creek, and Browns River. Instead of following the route around the edge of the Plains Rivulet, the new pipeline followed a direct line through the valley and was made of steel since the concrete pipeline could not handle the higher pressures in the 100m drop into the valley. This section of steel pipeline is called the 'Siphon' and is representative of an inverted siphon.

Hume's success in this Tasmanian experiment assisted in their global recognition and subsequent expansion; by the early 1920s they had made, produced and sold reinforced concrete pipes in New Zealand, Singapore, South Africa, England, and India (7).

2.5. Initial Leakage

Within the first year of operation the dam showed signs of cracking and severe leaks, with the worst leakages through the valve tower (located near the northern tip of the reservoir) and the radial joint between the arch and the right[27] abutment. The leakage through the dam wall was estimated at 1,140 kl/day (13.21 l/sec), whilst leakage through the valve tower was estimated to be 1,360 kl/day (15.71 l/sec) (3); the combined leakage was an estimated 2,500 kl/day, roughly equal to draining one Olympic size swimming pool per day.

The leakages gained the attention of not only the HCC but also the Kingborough Council[28], with concerns over the failure of the dam and their citizen's safety. E. M. de Burgh, Wade's successor,

[23]HOBART WATER SUPPLY, 1916, loc.cit.

[24]The innovative humespun pipes are constructed by spinning the concrete in an open cylinder mould on friction rollers. A workman would fill the mould whilst it was spinning to evenly distribute the concrete. Through centrifugal action water was forced out of the concrete into the centre, giving a high density, uniform concrete pipe. The pipe was further strengthened by incorporating a steel wire mesh into the mould; the addition of reinforcement allowed the pipes to withstand internal pressures (5).

[25]HOBART CITY COUNCIL, *The Mercury*, 14 May 1918, p. 6.

[26]THE HUME PIPE, *The Mercury*, 13 February 1918, p. 3.

[27] Standard orientation for dams assumes a person is standing on the dam wall with the stored water to their back, facing downstream.

[28]KINGBOROUGH COUNCIL, *The Mercury*, 18 October 1918, p. 5.

was contracted to report on the stability of the dam wall, and it was found to be stable despite the leaks[29].

Upon emptying the reservoir H. E. Bellamy, the City Engineer, noted significant softening of the upstream face of the dam, as well as the roof of the outlet tunnel, which was soft enough that drills could be pressed through with little difficulty. Near the right radial joint, concrete had deteriorated to a depth of 600mm. Bellamy recommended and assisted in the restoration of the reservoir which involved enclosing the valve tower in 150mm of special concrete (3), cutting out areas of soft concrete, and concreting the upstream face of the dam[30]. The leakages, caused by softening of the concrete, were due to low quality sand (3). Bellamy found that the sand had a high level of magnesium salts which caused the concrete to soften. The sand used had been condemned, during the construction of Ridgeway Dam, by many of the engineers involved; some of the engineers concerned were Milles[31], G. O. Smith[32], and R. R. P. Hickson[33].

2.6. 1960s Remedial Works

In 1962 Ridgeway Dam underwent a stage of remedial work as leakage had increased to 230 kl/day (3). Due to water shortages the HCC considered the possibility of increasing the height of the dam, and to do so sought the advice of the Cementation Company (Australia) Ltd (8). The company had experience in dam analysis and had recently completed pre-stressing works in the construction of the Catagunya dam.

The Cementation Company reported that there was insufficient resistance to overturning and sliding in the abutments, and due to its thin profile and the state of dam building at the time of construction, it could not recommend raising the dam without first completing remedial measures in order to bring the dam up to current standards (9). The HCC contracted the Cementation Company to complete the remedial works, but opted to leave increasing the height until such time as was economically viable. The remedial works involved the installation of 23 post-tensioned cables loaded to 217-220 tonnes, and each comprising 102 high tensile wires of 0.2 in. diameter (10). Grouting was also completed in the arch using a double-shot grout, and the contact between the foundations and the concrete was pressure grouted; these works stabilised the dam and reduced the leakage by 99% (11).

2.7. 1980s Investigations

In 1987, GHD completed a review of the dam and found that the gravity abutments were not capable of resisting the normal loading imposed on them, considering both the water loading and estimated foundation pore pressure. This review considered the stability of the gravity abutments in isolation and did not consider the additional forces imposed upon them by the arch. GHD's review recommended a detailed stress calculation of the dam including measurement of pore pressures, and repairs to a few major leaks (despite leakage the overall structure was sound). Leakage does

[29]RIDGEWAY RESERVOIR, *The Mercury*, 8 October 1918, p. 2.
[30]RIDGEWAY RESERVOIR. OUTLET TUNNEL LEAKING. FAULTS TO BE REMEDIED, *The Mercury*, 13 March 1919, p.4.
[31]RIDGEWAY RESERVOIR DISPUTE. *The Mercury.* 27 October 1914, p. 2.
[32]RIDGEWAY RESERVOIR DISPUTE. *The Mercury.* 16 October 1914, p. 2.
[33]RIDGEWAY RESERVOIR DISPUTE. *The Mercury.* 15 October 1914, p. 2.

lead to the leaching of materials which could modify the load carrying mechanism to the detriment of the overall structure (12).

Two years later in 1989 the Hobart Regional Water Board commissioned the Hydro Electric Commission (HEC) to carry out a stability analysis of the gravity abutments, this time taking into account thrust forces from the arch. The HEC concluded that the gravity abutments were stable and that their stability was significantly enhanced by the thrust forces of the arch; the analysis found that the abutments had a sliding factor (total driving forces/total resisting forces) of between 0.5 and 0.7 (13).

2.8. 1990s Repairs and Bypass Pipeline

Further investigations in 1999 observed holes in the upstream face along the construction joints, which enable relatively clear passage of water to the downstream face. The investigations led to a series of repairs, which were completed once the reservoir water level was lowered to an accessible level, through the injection of resin under pressure (14).

Seven sites were nominated for repair, with the concrete surface cleaned and opened out to expose sound concrete. The joints were then filled with a quick-setting polymer-modified resin. The two-shot repair including a foaming resin which was mixed and injected into the joint via mechanical pump with a follow-up consolidating resin which filled the voids in the foam. Water was initially pumped into these joints as a reactant for the resin and on several occasions jets of water were observed, ejected due to the expanding foam resin. A total of 42 litres of resin was used in the repairs.

During this period Hobart Water identified the need to construct a bypass pipeline as a measure to be able to supply water if Ridgeway Reservoir should become unavailable as a water source. The construction of the bypass pipeline should allow water from the Lower Reservoir Pump Station and Mount Wellington catchments to be piped directly to the Kingston and Bonnet Hill pipelines.

3. Specifications

3.1. Ridgeway Dam

Ridgeway is described as *"a thin arch dam, reinforced with 27kg steel rails at 1.8m both ways, at each face, with mass concrete abutments, and extra reinforcement in the form of four rails along the length of the dam below the coping."* (3) The abutments were constructed with a sandstone plum concrete, whilst the arch was built in solid concrete above 85ft. (25.9m); assuming this is 85ft (25.9m) above the bottom of the reservoir, then the arch is in solid concrete from the coping down 25ft.(7.62m), and below this level the arch was constructed in dolerite plum concrete. The capacity was estimated during construction to be 783.6Ml, whilst it is listed by the Australian National Committee on Large Dams (ANCOLD) as having a capacity of 942.7 Ml. There is also a conflict between the Top Water Level (TWL) given in the plan of the dam and that given in Crawford's report (3), with a TWL of 275.8m and 277.4m (above S.L.) respectively.

The 1960s remedial works modified the dam, and it now includes 23 post-tensioned cables in the gravity abutments to increase its stability.

3.1. Key Dimensions[34]

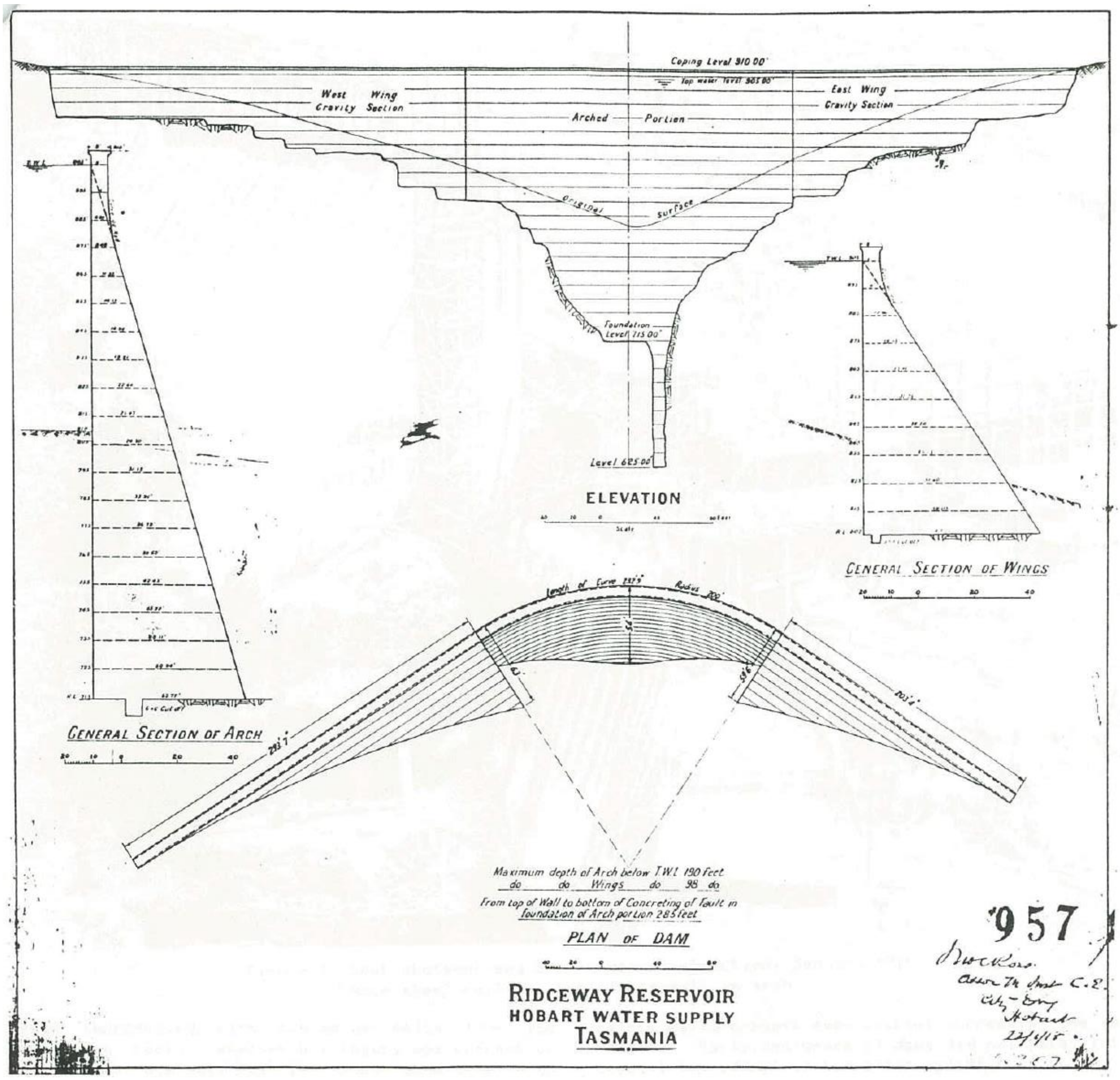
Length	**[m]**	**Thickness**	**[m]**
Total crest length	222.40	*Abutments & arch at top of coping*	2.44
Arch	70.94	*Arch under coping*	1.83
Left abutment	61.98	*Arch at foundation*	16.40
Right abutment	89.48	*Left abutment*	19.50
		Right abutment	17.70

Depth	**[m]**		**[m^2]**
Top of arch - foundation, maximum	61.30	**Reservoir Area[35]**	78,000
Top of arch – bottom of reservoir	33.53		
Top of arch - bottom of trial shaft	86.90		**[Ml]**
Maximum depth of water	29.00	**Capacity[35]**	942.70[36]

	[m^3]		**[m^3]**
Total Volume Excavated[37]	34,405[38]	**Total Volume of Concrete[36]**	36,259[39]

[34] Dimensions based off those given in Crawford's 1988 report (3)
[35] At full supply level (277.4m above S.L.)
[36] Equivalent volume of 377 Olympic-size swimming pools (given OSSP Volume = 25 Ml)
[37] RIDGEWAY RESERVOIR. DIMENSIONS OF THE WALL. CAPACITY OF THE DAM, *The Mercury*, 8 June 1917, p. 4.
[38] Equivalent volume of 13.76 Olympic-size swimming pools (given OSSP Volume = 2,500 m^3)
[39] Equivalent volume of 14.5 Olympic-size swimming pools

3.2. Plan of Ridgeway Dam Wall



3.2. North-West Bay Pipeline

The pipeline was constructed between 1916 and 1918 and runs from the North-West Bay River weir 13k around the mountain to Ridgeway, with several intakes including intakes on Long Creek, Fork Creek and Browns River. The pipeline is no longer in use with the steel 'siphon' in the valley of the Plains Rivulet in disrepair and sections of pipeline destroyed from landslides. The information available suggests that currently the pipeline runs along the track of the original iron pipeline to the North-West Bay River, which finished construction in 1901. Discussion on upgrading this original pipeline began as early as 1922[40].

[40] HOBART'S WATER SUPPLY. N.W. BAY RIVER PIPELINE. DISCUSSSION IN CITY COUNCIL, *The Mercury*, 28 February 1922, p. 5.

3.2. Pipeline Specifications

Pipeline Segment		Type	Diameter [in.]	Length [m]
From	***To***			
NW Bay River	*Watchorn's Hill Basin*	Steel	15	1,338
		Humespun	15	5,104
Watchorn's Hill Basin	*Ferntree Basin*	Humespun	18	3,982
Ferntree Basin	*McDermott's Saddle*	Humespun	18	2,392
McDermott's Saddle	*Ridgeway Reservoir*	Humespun	15	241
			Total	**13,058**

The 1918 pipeline was tested to a maximum pressure of 1Mpa, with standard working pressure at 717kPa[41]. It is estimated that, with the 100m drop of the Siphon, the steel pipes withstood pressures of up to 2MPa.

4. Engineering Practices

4.1. Arch Dam Design

The first arch dam built in Tasmania utilised some of the most advanced dam design techniques in the world at that time and represents the final iteration of the Darley-Wade dams constructed in NSW. In comparison with similar dams constructed in NSW, Ridgeway was designed to be significantly larger than the Darley-Wade dams. Whilst other designs had been considered for Ridgeway, lack of suitable local material encouraged the concrete arch design to be used; Wade may also have been biased towards the design due to his experience in arch dam construction in NSW, and the fissure may have discouraged a concrete gravity dam design. A gravity dam would have had significantly higher shear stresses over the fissure than the arch dam constructed.

4.1 – Darley-Wade Dams with Gravity Abutments

Name	Location	Max. Height (H) [m]	Total Length [m]	Top Thickness [m]	Base Thickness (E) [m]	Arch Radius [m]	Capacity [Ml]	E/H	Construction Date
Hardy's Folly	Cootamundra	14	195	0.9	3.96	76.2	515	0.28	1898
Cordeaux No. 1	Wollongong	12.8	163	1.1	3.5	61	606	0.28	1899
Ridgeway	Ridgeway	**61.3**	**224.5**	**1.83**	**16.4**	61	**942**	0.27	1911

4.1.1. Constant Radius

The constant radius technique for dam design was first used in the construction of the Zola Dam, built in the 1840s in France. This technique became widely used in the design of arch dams, and was used by Darley and Wade in NSW, where thirteen arch dams were built between 1890 and 1908

[41] HOBART CITY COUNCIL. RIDGEWAY RESERVOIR PIPE LINE TESTS, *The Mercury,* 14 May 1918, p. 6.

(15). The next innovation in dam design was the constant angle dam technique, formulated by L.R. Jorgensen, with the first dam of its type, Salmon Creek Dam, constructed in 1914, Alaska, USA.

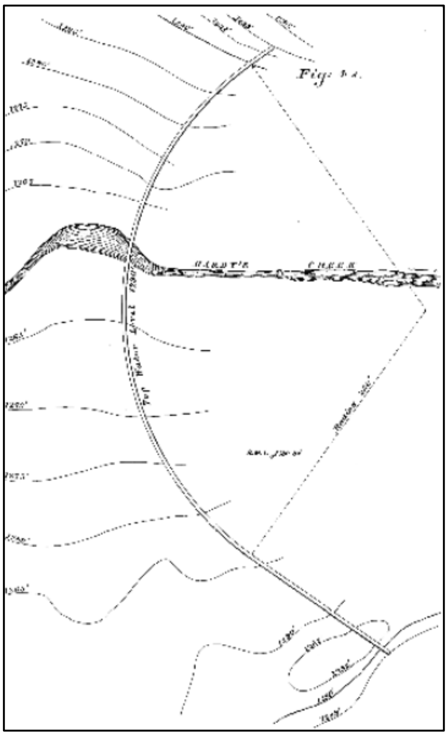
It has been remarked that Ridgeway would have benefited from the constant angle technique. W. H. R. Nimmo (16) and S. Giudici (17) separately stated that Australian dams during the period of 1910-1935 could have been improved by utilising the constant angle design, however both consider the construction of Ridgeway as being from 1914-1919, discounting the period of the dam's design. Wade submitted his final report on the dam design in 1909, with plans completed by the following year, four years prior to L.R. Jorgensen's innovation. Nimmo (16) and Giudici (17) also discount the period it would take for a technique first used in 1914 in USA to be adopted in Australia[42].

4.1.2. Gravity Abutments

Darley introduced the use of gravity abutment walls to the arch dam design in order to deal with wider valleys, since strength of the arch design relied on a specific range of angles. Gravity abutments were also useful for gentle gradient valleys where a strong valley wall abutment could not be achieved. Ridgeway was the first of the Darley-Wade dams with two gravity abutments, with the Hardy's Folly dam being the first thin arch dam with an abutment, constructed in 1898.

It is uncertain though whether Hardy's Folly's water level was ever high enough for significant use of the gravity abutment and so Upper Cordeaux No.1 may be the first to utilise abutment forces in a gravity abutment; indeed, the plan of the Upper Cordeaux No. 1 dam shows thickening of the gravity abutment whereas Hardy's Folly has a continuous thin dam wall which does not indicate design to compensate for overturning and sliding.

4.3. Hardy's Folly (Cootamundra) Dam Plan (15)



[42]Whilst Ridgeway was designed before Salmon Creek was completed, it was not until 1958 that Tumut Pond Dam, the first constant angle dam in Australia, was constructed (17); this 44-year gap is in agreement with Nimmo's and Giudici's opinion the dam construction technology in Australia stagnated in the early 1900s.

4.1.3. Arch Reinforcement

De Burgh introduced the use of Steel reinforcement in the design of the de Burgh and Barren Jack City dams, completed in 1908, and 1909 respectively. It was agreed by both de Burgh and Wade however that steel reinforcement was not a necessity in arch dam design. Wade had initial reservations about its use; however, this approach was adopted in the design of Ridgeway.

4.1.4. Hydraulic Uplift

In the restoration of the Ridgeway Reservoir it was commented on the omission of hydraulic uplift in its initial design. Considering the state of dam design in 1910, the first rumble of hydraulic uplift calculation was in 1888 by James B. Francis, who recommended applying full hydrostatic pressure at the upstream heel of a dam, diminishing to zero pressure at the toe. Hydraulic Uplift did not become a common issue until the catastrophic failure of the St. Francis Dam, USA, in 1928. This failure occurred in the same month that a precedent-setting article (18) on hydraulic uplift was published in the March 1928 issue of ASCE Proceedings, authored by J. Hinds, a new employee of the City of Los Angeles Bureau of Waterworks and Supply. The article along with the St. Francis failure cemented the concept of hydraulic uplift into common practice (19); this was two decades after the design of Ridgeway.

4.1.5. Concrete

The concrete used in the construction of Ridgeway was of generally poor quality. In order to make high quality concrete, high quality sand and aggregate is needed. Sand is mixed with cement to help bind aggregate, however, carting high quality sand from Long Beach or along the foreshore was costly and so the Contractor sought to find a local source of sandstone suitable for crushing into sand[43]. They eventually set up a quarry for this purpose on Chimney Pott Hill.

Wade commented on the sandstone chosen stating, that although fine, was suitable, as long as the coarser beds were used (20). It should be noted that whilst Wade was experienced in dam design and construction, he was not familiar with the novelties of Tasmanian geology; Tasmanian sandstone is of a different composition to sandstone used in NSW.

Despite Wade's confidence in the sandstone, three other engineers later condemned the use of the sand. Milles opposed the use of the sand since it was too fine and contained a high percentage of clay (21). Hickson, a Sydney Engineer who came down to review the lack of progress, condemned the use of the sand stating "*I would no more use that sand in a work of mine than I would fly*" (22). Smith also condemned the use of the sand after finding the test briquettes, made with the sand, were of a significantly lower strength[44]. In response to the leakages in 1918, the Town Clerk authored a report stating that the sand "*was so dirty that it failed to bind satisfactorily with the Portland cement*." (23)

Bellamy found that the concrete had a higher quantity of magnesium in it and suggested this as the reason for the softening and leakages. His hypothesis was that the sandstone had been metamorphosed by surrounding dolerite and impregnated with magnesium salts (3) from a band of shale. The quarry for the sandstone was described at the time as being three bands of good stone (sandstone), with the assumption that bands of shale were also present.

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[43]THE RIDGEWAY RESERVOIR. THE PROGRESS BEING MADE, *The Mercury*, 5 February 1912, p. 7.

[44]RIDGEWAY RESERVOIR DISPUTE. CONTRACTORS AND THE CORPORATION, *The Mercury*, 16 October 1914, p.2.

There has been no evidence to suggest that another source of sand, other than the sand from Chimney Pot Hill was used. In order to cut costs and reduce their losses the Contractor used locally sourced sand instead of higher quality sand from the foreshore. This sand was unsuitable for use in dam construction and was used despite the protests of the engineers involved, causing the recurring leakage issues with Ridgeway.

Following a petrographic examination of the concrete in 1997 (24) it was found that the coarse aggregate comprised approximately 80% dolerite and 20% sandstone, whilst the fine aggregate comprised 90% quartz and quartz sandstone and 10% doleritic materials.

4.1.5.1. Analysis Techniques

It is difficult to know what the standard was in checking sand or sandstone for suitability in concrete as various simple tests of soil were common at the time. The simplest test, recommended by a Director of Chemistry in 1939 was to test the sand for salt by watering it, stirring and tasting the decanted water, if the water tasted salty, the salt content was too high to make effective cement[45]. Another method which seemed common in 1912 was to mix the crushed sandstone in a mason jar, with water, and let the sediment settle out. The clay and loam would settle above the sand and if there was more than half an inch, then the sand was rejected or washed[46]. A more rigorous method for testing the sand was to have a chemical analysis completed so as to give a clear picture of the content of the sandstone; since Bellamy is said to have analysed the sandstone after the leaks were discovered (3) and found high levels of magnesium salts it is assumed he used the last method[47].

4.1.6. Post-Tensioning

Post-stressing (the technique of using tensioned cables to anchor a dam wall to its foundation, artificially increasing the dam wall's weight) was first used in 1956 on the Allt-na-Lairige concrete gravity dam in Scotland (25). The Cementation Company pioneered this new technique, in the next two uses of post-stressing, on the Steebas Dam in South Africa and the Waitaki Dam in New Zealand in the late 1950s. Prior to the post-tensioning works on the Ridgeway Dam, Cementation Co. completed similar works in the construction of the Catagunya Dam in Tasmania in 1961; the techniques and steel cables used in Catagunya were repeated in their works on Ridgeway.

The main concern with steel use in dams is the potential for corrosion. When grouting a steel cable into a dam care needs to be taken to ensure a water-tight enclosure, since there's the possibility of grout settling, leaving air pockets and the steel cables exposed. The use of thick grout mix (water/concrete ratio of 0.4-0.45) and waterproofing of the duct walls via pre-grouting reduced this risk in the post-stressing process (13).

The nominal requirement for concrete cover of reinforcing steel and tensioned cables is 40-50mm in an aggressive environment, while the concrete cover of steel cables in the gravity abutments are about 550mm; more than enough protection in this environment.

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[45]SALT CONTENT OF SAND WHEN USED FOR CONCRETE POSTS, *The Mercury*, 21 September 1939, p.2.
[46]Testing Sand for Concrete, *The Mercury*, 1 June 1912, p.3.
[47]No report on the results of the analysis has been uncovered, other than mentions by Crawford (3) and Nimmo (16) in their respective reports.

4.2. Transfer of Experience

It was some twenty years after the construction of Ridgeway Reservoir that a large arch dam[48] was built in Tasmania which was the Clark Dam, built to improve the output of the Tarraleah Power Scheme, which also utilised the constant radius design. There were two other dams built between Ridgeway and Clark but these were of rock-fill and earth-fill embankment types.

The reason why arch dams were not used in these instances is not clearly known, but up to 2008 there were only five of a total of 100 dams constructed with an arch design (including Ridgeway and Clark), with the most recent dams constructed using a double curvature design. It is assumed that arch dam rarity in Tasmania comes from the geography and economy of construction, despite using less concrete than a concrete gravity dam. Often the geography allowed for inexpensive construction of earth-fill and rock-fill dams. The rarity of arch dams in Tasmania and the two decade gap in the construction of Ridgeway and Clark suggests that knowledge was not transferred from the design of Ridgeway, to the construction of Clark.

5. Significant People

5.1. Bellamy, Herbert Ernest (1877-1947)

Bellamy was born in Bedfordshire in 1877 and educated in Lancashire, England[49]. His early career was spent studying water supplies and sewage disposal works in USA and Germany. He worked as the resident engineer on Sydney sewerage works assistant engineer of Colombo main drainage works, Chief engineer of Hobart, Hydraulic engineer of South Australia and consulting engineer about 30 city and municipal councils.

In Hobart, Bellamy worked on many projects including the construction of the sewerage scheme at Queenborough, the New Town sewerage scheme, Collins St rivulet diversion, Lochner street housing scheme, the lions' den and Polar-bear pit at the zoo, the John Colvin memorial grandstand, and improvements to Hobart's water supply system[50]; most notable among his works was in reducing the dam leakage at Ridgeway and his report on the proposed Lake Fenton water scheme in 1922. Bellamy died in Hawthorn, Victoria on 7 September 1947.

5.2. De Burgh, Ernest Macartney (1863-1929)

De Burgh was educated at the Royal College of Science in Ireland. Prior to moving to New South Wales, he worked on railway construction. In 1885 he was appointed to the Public Works Department and was involved in railway construction as a bridge engineer. In 1904 de Burgh studied dam construction and water supply design in England and France. He is credited with introducing steel reinforcement to arch dam design with the construction of the De Burgh and Burrinjuck dams.

5.3. Hume, Walter Reginald (1873-1943)

Hume was born in 1873 in Melbourne and spent his early years as a plasterer. In the 1890s he and his brother Ernest established a workshop in Malmsbury where they produced fencing droppers under Walter's patent. Their business was very successful, but as pastoral capital works declined the

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[48]As appears on the list of Large Dams by ANCOLD.
[49] HYDRAULIC ENGINEER, *The Mercury*, 4 May 1929, p. 4.
[50] THE CITY ENGINEER. MR H. E. BELLAMY'S DEPARTURE, *The Mercury*, 18 February 1925, p. 9.

brothers turned their attention to other avenues. They manufactured ornamental steel fencing in Adelaide until 1910 when Walter applied their fence painting process to manufacturing concrete pipes. In this year they formed Humes' Patent Cement Iron Syndicate Ltd. Hume's inventive centrifugal process to manufacture high quality concrete pipes revolutionised the industry. The success of his pipes in the North West Bay pipeline in Tasmania spurred the wide use of his invention, enabling his firm to expand globally through royalty agreements and joint ventures. (26)

5.4. Milles, R. S. (1858-1925)

Milles was born in 1858 in Kent, England. He was educated in engineering at King's College, London, and serviced his apprenticeship in Leeds. Prior to moving to Tasmania in 1883 he worked under the City Engineer of Wolverhampton. In Tasmania he was employed by the Government in the Public Works Department. He worked as assistant engineer on the Scottsdale railway, the Mt. Cameron water-race, and worked under Engineer-in-Chief, Mr Fincham, on the designing and drafting branch. Milles also designed and was resident engineer for the construction of the Bridgewater Bridge and undertook restoration works on the Lower Reservoir. His main accomplishment concerning Ridgeway was in its preliminary surveying and assistance in design.

5.5. Ross, John C.

Ross was City Engineer in Hobart between 1913 and 1918. His major works were in the testing and design of the North-West Bay pipeline. He also designed the sewerage scheme for Queenborough, and the water supply schemes for Kingston, Bellerive and Lindisfarne, including the pipeline under the Derwent River. In 1916 Ross travelled to Adelaide to test the reinforced concrete pipes built by Hume Bros. Cement Iron Company Ltd, which were used as a replacement for iron pipes in the Ridgeway scheme. Following his success experience with Hume Bros. on the North-West Bay pipeline he left Tasmania in 1918 in order to take up a new role as an engineer for Hume in their expansion to South Africa.

5.6. Wade, Leslie Augustus Burton (1864-1915)

Wade was born in Singleton, New South Wales. He was trained in surveying and worked for NSW Department of Public Works from 1880 to 1890, and 1892 to 1912. In 1913 he took on the role of Commissioner of the Water Conservation and Irrigation Commission (27). He is known for his exceptional work on thin arch dams. Thirteen arch dams constructed in NSW gained attention in London for their slender cross-sections. These dams, coined the 'Darley-Wade' dams, signify an era of high quality arch dam design and construction.

6. References

1. **Futurepast Heritage Consulting Pty. Ltd.** *Hobart Mountain Water Supply System: Conservation Management Plan (Final Report - March 2012).* 2012.

2. **Milles, R. S.** HIGH LEVEL RESERVOIR. TRIAL TESTS AT RIDGEWAY SITE. *The Mercury.* 11 November 1908, p. 2.

3. **Crawford, Philip Godfrey.** *RIDGEWAY WATER SUPPLY DAM.* Hobart : Hobart City Council, 1988.

4. **Milles, R. S.** REPORT OF DIRECTOR OF WATERWORKS. *The Mercury.* 7 March 1913, p. 6.

5. **Ross, J C.** *N.W. Bay River Pipeline - REPORT re REINFORCED CONCRETE PIPES (Hume Bros.' Patent) .* Hobart : s.n., 1916.

6. *re Tenders for pipes of New Water Supply.* Hobart : s.n., 21 February 1919. Hobart City Council Meeting Minutes.

7. *A Pipe Dream Come True: the International Expansion of the Hume Pipe Company in the 1920s.* **Emerson-Elliot, Richard.** 4, 2004, Business History, Vol. 46, pp. 544-567.

8. **Crawford, Philip Godfrey.** LETTER: P.G. Crawford to Hydro-Electric Commission. 25 October 1960.

9. **Cementation Co.** LETTER: Cemetation Co. to Hobart City Council. 8 November 1961.

10. *The Strengthening of Ridgeway Dam, Hobart, Tasmania.* **Carlile, J. L.** Hobart : ANCOLD Bulletin, 1966.

11. **Crawford, Philip Godfrey.** *Ridgeway Dam Progress Report to 13.9.62.* Hobart : s.n., 1962.

12. **GHD.** *Dam Surveillance Report for Hobart Regional Water Board.* Hobart : s.n., 1987.

13. **HECEC Australia Pty Ltd.** *Ridgeway Dam - Life Expectancy Review.* Hobart : Hobart Water, 1997.

14. **HECEC Australia Pty Ltd.** *Concrete Repairs to the Downstream Face of Ridgeway Dam.* Hobart : Hobart Water, 1999.

15. *Concrete and Masonry Dam-Construction in New South Wales.* **Wade, L. A. B.** 9, London : s.n., 1909, Min. of Proc. of Instn. of Civil Engineers, Vol. 178, pp. 1-26.

16. *Historical Review of dams in Australia.* **Nimmo, W. H. R.** 18, 1966, ANCOLD Bulletin, pp. 11-51.

17. **Australian National Committee on Large Dams.** *Dam Technology in Australia 1850-1999.* 2000.

18. *Uplift Pressures Under Dams: Experiments by the United States Bureau of Reclamation.* **Hinds, J.** Los Angeles : ASCE Proceedings, 1928.

19. **Rogers, J. D.** *The 1928 St. Francis Dam Failure and Its Impact on American Civil Engineering.* 2003.

20. **Wade, L. A. B.** THE RIDGEWAY RESERVOIR. THE REPORT OF MR. WADE. *The Mercury.* 14 May 1912, p. 3.

21. **Milles, R. S.** RIDGEWAY RESERVOIR DISPUTE.CONTRACTORS AND THE CORPORATION. *The Mercury.* 27 October 1914, p. 2.

22. **Hickson, R. R. P.** RIDGEWAY RESERVOIR DISPUTE. CONTRACTORS AND THE CORPORATION. *The Mercury.* 15 October 1914, p. 2.

23. **Bottrill, W. E.** HOBART CITY COUNCIL. A REVIEW BY DR. BOTTRILL. *The Mercury.* 24 December 1919, p. 8.

24. **Bottrill, R. S.** *Pertrographic Examination of Concrete Cores from the Ridgeway Dam, Hobart, for Indications of Alkali-Aggregate Reactions.* Hobart : (unpublished), 1997.

25. **The Engineering Heritage Committee, Tasmania Division.** *Catagunya Dam - Tasmania.* Hobart : s.n., 2000.

26. **Snooks, G. D.** Hume, Walter Reginald (1873-1943). [Online] Australian Dictionary of Biography, National Centre of Biography, Australian National University. [Cited: 28 January 2015.] published first in hardcopy 1983. http://adb.anu.edu.au/biography/hume-walter-reginald-6764.

27. **Chanson, H. and James, D. P.** *Historical Development of Arch Dams: from cut-stone arches to modern concrete designs.* Brisbane : Department of Civil Engineering, The University of Queensland, 2002.

28. THE RIDGEWAY RESERVOIR. REPAIRS URGENTLY REQUIRED. DISCUSSION AT CITY COUNCIL. *The Mercury.* 6 May 1919, p. 5.

29. **Lewis, Miles.** *Two hundred years of concrete in Australia.* North Sydney : Concrete Institute of Australia, 1988.

30. **Chanson, H. and James, D. P.** *Historical Development of Arch Dams in Australia: from advanced designs to engineering failures.* s.l. : Department of Civil Engineering, The University of Queensland, 1998.

7. Appendix (Pipeline Development 1858-1918)